ELECTRIC LIGHTING SYSTEM AT DOWNERS GROVE, ILL.

BY

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ARMOUR INSTITUTE OF TECHNOLOGY

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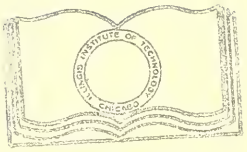
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Rehabilitation of the
municipal electric lighting

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Rehabilitation

of the

Municipal Electric Lighting System

at

Downers Grove, Ill.

A THESIS

PRESENTED BY

H. A. Drew C. R. Schuler

TO THE

PRESIDENT AND FACULTY

OF

ARMOUR INSTITUTE OF TECHNOLOGY

FOR THE DEGREE OF

BACHELOR OF SCIENCE IN ELECTRICAL ENGINEERING

HAVING COMPLETED THE PRESCRIBED COURSE OF STUDY IN

ELECTRICAL ENGINEERING

May, 1912.

Approved

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Downers Grove is a suburban community situated about twenty miles west of Chicago, on the Chicago, Burlington and Quincy Railroad. During the last decade it has grown from a cluster of frame buildings at a country crossroads into a progressive town of 2500 inhabitants. This transition has been accomplished largely through the acquisition of modern improvements; paved streets, cement walks, storm and sanitary sewers, gas mains, and a city water system having been installed to meet the demands of progressive citizens. In fact Downers Grove enjoys all of the municipal conveniences that are usually found in towns of this size, with the exception of a satisfactory electric lighting system.

At present the electric lighting plant is operated, together with the pumping station, as a municipal power plant. The equipment of the plant includes four 50 H.P. horizontal hand fired boilers, one 75 H.P. direct acting, duplex pump, and one 100 h.p. simple, non-condensing engine, belt connected to a 70 kw. 2200 volt, single phase generator. The pressure is stepped down to 110 volts for house lighting. Series tungsten lamps have been recently installed for street lighting, displacing a carbon arc system.

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The plant was erected over fifteen years ago and was designed to meet the conditions existing at that time. A small air-compressor was used for the city water system, but the growth of the town necessitated the installation of the 75 h.p. pump. The electrical equipment and boilers are, however, still in service and according to the engineer in charge, the boilers, engine, and generator are completely worn out. The single unit is operated continuously from 4 P.M. to 8 A.M., and when a shutdown occurs the town is plunged in darkness until repairs can be made. This has occured so frequently during the past year, that the service is now considered absolutely unreliable. The street lighting is deficient; 40 watt lamps being used, placed about 500 feet apart. This deficiency is generally recognized, but more illumination is impossible because the plant is now operating at its full capacity. The supplying of power to small manufacturing concerns is out of the question with the present equipment, altho several firms have petitioned the village to enlarge the plant, in order that they might buy central station power. In a few instances, companies have removed to other locations where this privilege is available.

It is at once obvious that this electric lighting system is inadequate and unable to meet its demands. To correct this condition, two alternatives present themselves. The station may be enlarged and continue to operate as a municipal institution, or a franchise may be granted to some public service company that will maintain a substation in the town.

Applications for a franchise have been received by the village from several corporations, the most favorable coming from the North Shore Electric Co., This company offers to buy the present electrical equipment for $15,000.00, and to sell power at 10 cents per kw. hour. Inasmuch as the present rate is 15 cents per kw. hour, and the $15,000.00 bonus could be used in building a city hall, which is much needed, this offer received considerable attention.

The village board of aldermen looked upon the proposition with favor, altho opponents of the scheme pointed out conclusively that the electric lighting plant, even in its worn out condition, had been in a source of revenue to the village. The final decision however, in a matter of this kind rests with the voters and accordingly, in October 1911 the question was sub-

mitted to them at a special election. By a large majority they decided against the granting of a franchise and by this action practically recommended the only other course of procedure, viz., the rehabilitation of the plant. To design a new lighting plant for this town and then to determine the rationality of this decision, are the purposes of this thesis.

The design of the proposed street lighting system takes into account future demands, by providing lamps where they will be needed as the town expands. 200 watt series tungstens will be arranged in groups of twenty lamps each. In the residence sections of the town, they will be placed at appropriate places about 250 feet apart, and here the feeders will be carried overhead on wooden poles. Four ornamental iron posts will be placed at each of the principle business corners, each post carrying a 200 watt tungsten lamp. These lamps will be fed thru underground conduit. The power required by the street lamps will be $\frac{160 \times 200}{1000} = 32$ kw. Allowing 10% for line drop, the street lighting load becomes 35 kw.

The maximum power required for house lighting at present is 60 kw. With more reliable service and a

lower rate if it is reasonable to assume that this will be increased to 80 kw.

The firms that may be expected to buy power and the average load to be supplied are as follows:

Kelmscott Press.	25 H.P.
Potter Mfg. Co.,	20 H.P.
Dicke Tool Co.	50 H.P.
Illinois Heater Co.,	25 H.P.
Hawkins Pump Co.,	30 H.P.
	145 H.P. = 110 kw.

As Bowers Grove is essentially a residence town and because all of these manufacturing establishments have been located there for several years past, it is safe to assume that there will be no future development in this line and that the present demand for industrial power will not be increased.

The calculated load curve is based upon the foregoing assumptions with regard to street lighting, house lighting, and industrial power. The table shows the energy required per day for each branch of the service.

Industrial power	1100 kw. hours.
House lighting	495 " "
Street Lighting	385 " "
	1980 " "

Peak load = 170 kw.

In order to insure continuity of service in a plant of this kind, three generating units must be employed, any two of which will carry the peak load. With this idea in view and from a study of the load curve, it was decided to install three 150 h.p. four valve simple non-condensing Harrisburg engines. Each of these is to be belt connected to a 75 kw. 2200 volt three phase Westinghouse generator. Each generator will be belted directly to its own engine.

Altho the pump will usually be operated during the periods of non-peak electrical load, the boilers must be able to supply both the pump load and the peak electric l load, at the same time. The Harrisburg engine of this type is guaranteed to run at full load on 26 pounds of steam per indicated horse power with initial steam pressure at 100 pounds per square inch. The pump requires 150 pounds of steam per indicated horse power under the same conditions. Although the pump is rated at 75 h.p. its normal output is 55 h.p. and in no case would an output of 50 h.p. be exceeded.

The steam required for the generators is 170 x 26 = 4420 pounds per day and for the pump is 50 x 150

equals 7500 pounds per day, making a total steam consumption of 11,820 pounds per day. With steam pressure at 100 pounds per square inch (absolute) and feed water temperature at 190 degrees F, the factor of evaporation is $F = \frac{1185 - 190 \quad 32}{965.7} = \frac{1022}{965.7} = 1.07$

11,820 pounds of steam, under the given conditions are therefore equivalent to 11820 x 1.07 = 12800 pounds of steam, from and at 212 degrees F. The maximum boiler horse power required is $\frac{1280}{34.5}$ equals 370.

Three 100 h.p. boilers working at 25% overload would generate 375 boiler horse power, and as this maximum demand would be made only in emergencies, it is safe to make the calculations on the basis(to make the calculations on the basis)of overload capacity. The feed water in this plant rapidly forms scale and the boilers must be cleaned every month. An extra unit is therefore necessary, bringing the complete installation up to four 100 h.p. boilers. Babcock and Wilcox boilers of the horizontal water tube type, equipped with chain grates will be installed.

The coal will be unloaded from cars on a Chicago, Burlington and Quincy side track, into hoppers

directly in front of the boilers. Manual labor will be employed in feeding the coal onto the stokers and in removing the ashes.

A guyed sheet steel chimney will be erected upon a concrete foundation. The area of the chimney was made equal to one seventh of the grate area, the latter being .4 square feet per boiler horse power.

Area of Chimney $\frac{\pi d^2}{4} = \frac{370 \times 4}{7} = 21$ sq. ft.

Diameter of Chimney $\sqrt{\frac{21 \times 4}{\pi}} = 5.16$ feet.

Assuming a diameter of five feet the height was calculated from the formula, h.p. $= 3.33 A \sqrt{H}$

A effective area $A = .6 \sqrt{A}$

$19.6 - .6 \sqrt{19.6} = 1095$ sq. ft.

$H = \left(\frac{\text{h. p.}}{3.33 \times 16.95}\right)^2 \quad \left(\frac{370}{3.33 \times 16.95}\right)^2 = 43$ ft.

A 50 foot chimney was decided upon.

The steam from the engines and pump will be used in heating the feed water from a temperature of 60 degrees F. to 190 degrees F. A Wainwright multiflow closed heater will be used. An atmospheric heater working under the implied conditions requires about 6.3 square feet of heating surface to heat 1000 pounds of

feed water per hour. The total heating surface required is $\frac{12800}{1000}$ x 6.5 equals 80 square feet.

A direct acting simplex pump will take water from the city mains at an average pressure of 45 pounds per square inch and deliver it thru the heater into the boilers against a pressure of 100 pounds per square inch. The indicated horse power of the pump is

$$I = \frac{W \times 1.85 \ p \times 2.7}{33000 \times 60 \times S \times E} \times 2.$$

W equals pounds of water delivered per hour = 12800.

p. equals difference between boiler pressure and city water pressure, = 100 - 45 = 55 pounds per square inch.

S equals ratio of water delivered to piston displacement equals .8

E equals mechanical efficiency of pump = .65

I equals $\frac{12800 \times 1.85 \times 55 \times 2.5}{33000 \times 60 \times .8 \times .60} \times 2 = 4.26$ indicated horse power.

The switch board will consist of three generator panels and three feeder panels, one each of the latter being for street lighting, house lighting and industrial power. The 2200 volt buses will be located on the backs of the panels. The industrial power will be transmitted at 2200 Volts, three phase. The power for

lighting purposes will be transmitted in a similar manner to distribution centers. Here the street lighting system will be split up into single phase 2300 volt lines, while the power for house lighting will be stepped down to 110 volts and similarly split up into single phases.

The cost data for this station was compiled from trade catalogues wherever possible, but in some instances recourse was had to average values, reference being made to tables in Gebhardt's Steam Power Plant Engineering and recent papers on plant costs in the Proceedings of the American Institute of Electrical Engineers.

The cost of general equipment is divided between the electrical plant and the city water plant according to the relative pounds of steam required per day by each division, as given in the following table:

	Total Demand kw. hours.	lbs. of steam per kw. hour.	lbs. of Stm. p.h.	per cent.
Electrical Plant	2040	50	102000	71
Pumping Plant.	180	200	36000	25
			138000	

The steam consumption of the generators at full load is 40 pounds per kw. hour, but 50 pounds per kw. hour has been allowed in order to take into account the lower efficiencies of engine and generators at light loads.

Cost of general equipment.

Real Estate	$ 1000.00
Building, complete, including all foundations	15000.00
Stack	540.00
Boiler and setting	6000.00
Feed Pump	350.00
Feed Water Heater	300.00
Piping, Valves, Covering etc.	1500.00
Tool Room equipment	800.00
Engineering expenses	600.00
Miscellaneous	1000.00
	$ 26890.00

Chargeable to electrical plant (74%) $19890.00

Chargeable to pumping plant (26%) $7000.00

Cost of electrical equipment.

Generators	$ 3800.00
Exciters	180.00
Engines	5000.00
Switchboard	1200.00
Transformers	2400.00
Transmission system	4500.00
	$16980.00
74% of general equipment	19890.00
Total investment for electric plant	$36870.00

Annual fixed charges on investment.

Interest	6.0
Insurance	.5
Taxes	.5
Depreciation	4.0
Repairs	6.0
	17% of $36870.00 equals $6280.00

The annual cost of coal used for the generation of electricity is given by the equation:

$$C = \frac{b \times W \times 365 \times P}{B \times E \times 200}$$

b = B.T.U. in a pound of steam = 1022

B = B.T.U. in a pound of coal = 14500

W = pounds of steam per day = 138000

P = price of coal per ton = $3.00

E = efficiency of boilers = .6

$$C = \frac{1022 \times 138000 \times 365 \times 3}{14500 \times .6 \times 2000} = \$5860.00$$

The annual water consumption is equal to 138000 x 365 equals 50,500,000 pounds. The total amount of water handled by the pumping station is 650,000,000 pounds so that

$$\frac{50,500,000}{650,000,000 - 50,500,000}$$ or 8.4% of the fixed

charges and operating expenses of the pumping station may be used as the annual cost of feed water. The total investment represented in the pumping station is

26% of general equipment	$7000.00
Pump	3000.00
	$10000.00
Fixed charges 17% of $10000.00	$1700.00
26% of operating expenses	3190.00
	$4890.00

The annual cost of feed water then is 8.4% of $4890.00 or $410.00.

General operating expenses.

Coal		$5860.00
Water		410.00
Oil and Waste		600.00
Labor - Superintendent	$1200.00	
Two engineers	1680.00	
Three Firemen	2340.00	
Coal and Ash Handling	200.00	5420.00
		12290.00

Chargeable to electric plant (74%) $9100.00

Chargeable to pumping plant (26%) $3190.00

There are also two more operating expenses which must be borne by the electrical plant.

Lineman	$780.00
Collections	240.00
	$1020.00

This brings the annual operating expenses of the electrical plant up to $9100.00 + $1020.00 or $10120.00.

In order to compete with the North Shore Electric Co., this plant must pay interest on an

amount equivalent to the bonus offered by that company. An offer of $15,000.00 was made, part of which was in payment for the present equipment. The value of that part of the present equipment that will be used in the new system and the salvage on the rest of the equipment, must therefore be deducted from the amount of this offer in order to obtain what might be called the value of the franchise. It is obvious that if the village retains this franchise, the plant must pay interest on its marketable value.

Salvage on present equipment.

Real Estate	$1000.00
Boilers	200.00
Engines	200.00
Generators	200.00
Heater, pump and piping.	100.00
Tool room equipment	200.00
Transmission system.	1500.00
	3400.00

The value of the franchise is therefore equal to $15000.00 - $3400.00 or $11600.00, and the annual interest on the investment at 6% is $700.00

The total annual expenses of the electrical plant are as indicated.

Fixed charges	$6280.00
Operating expenses	10120.00
Interest on Franchise	700.00
	$17100.00

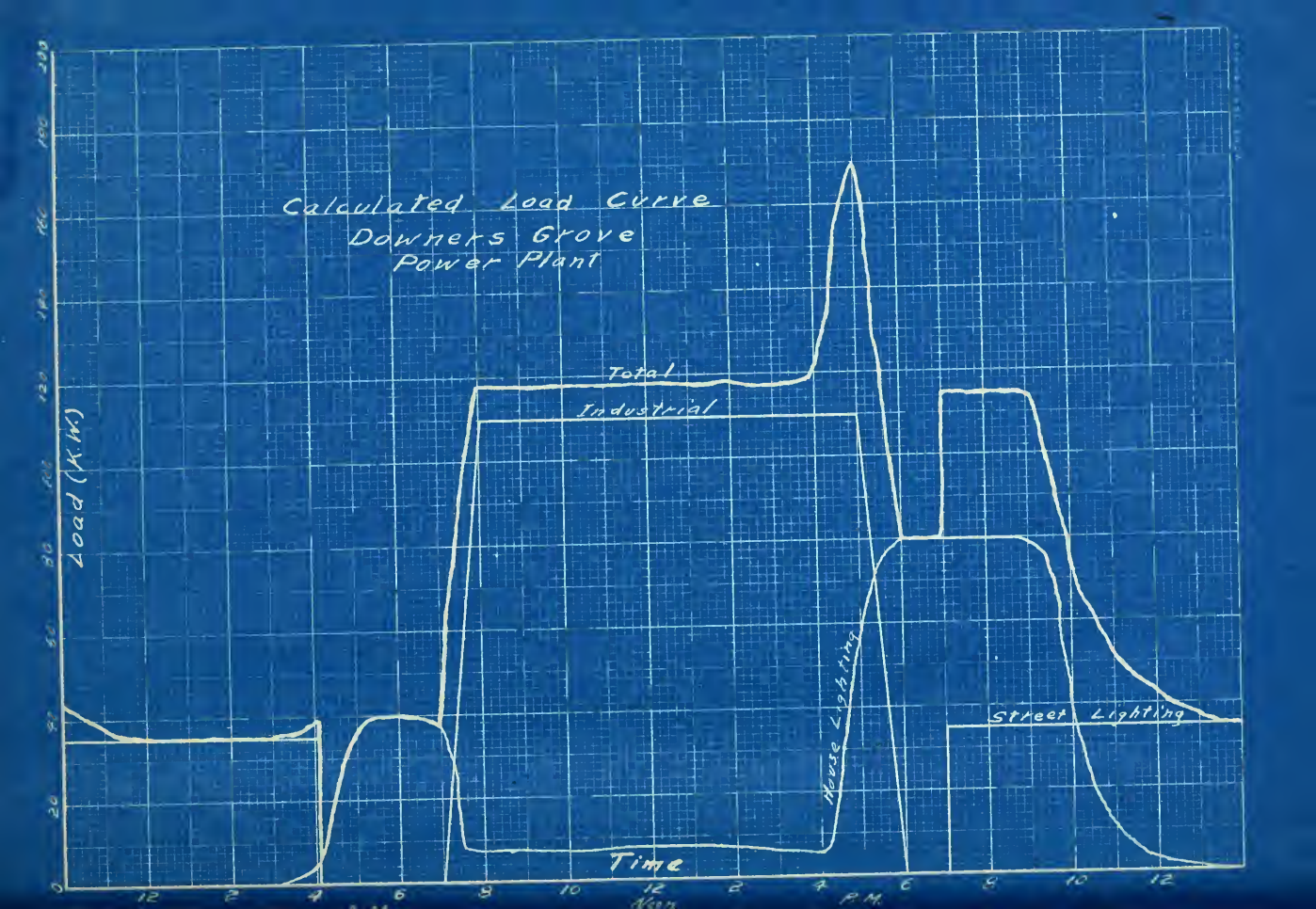
Since the North Shore Co. offered a rate of 10 cents per kw. hour to lighting costumers, and since a rate of 15 cents is now charged, a new rate of 10 cents per kw. hour would be satisfactory. The rate to power costumers would probably be fixed at 5 cents per kw. hour. The annual revenue from house lighting allowing 5% for line drop, would be .95 x 625 x .10 x 365 equals $21600.00. The revenue from industrial power would be .95 x 1100 x .05 x 365 equals $15200.00. The gross annual income is the sum of the two preceding items and amounts to $36800.00

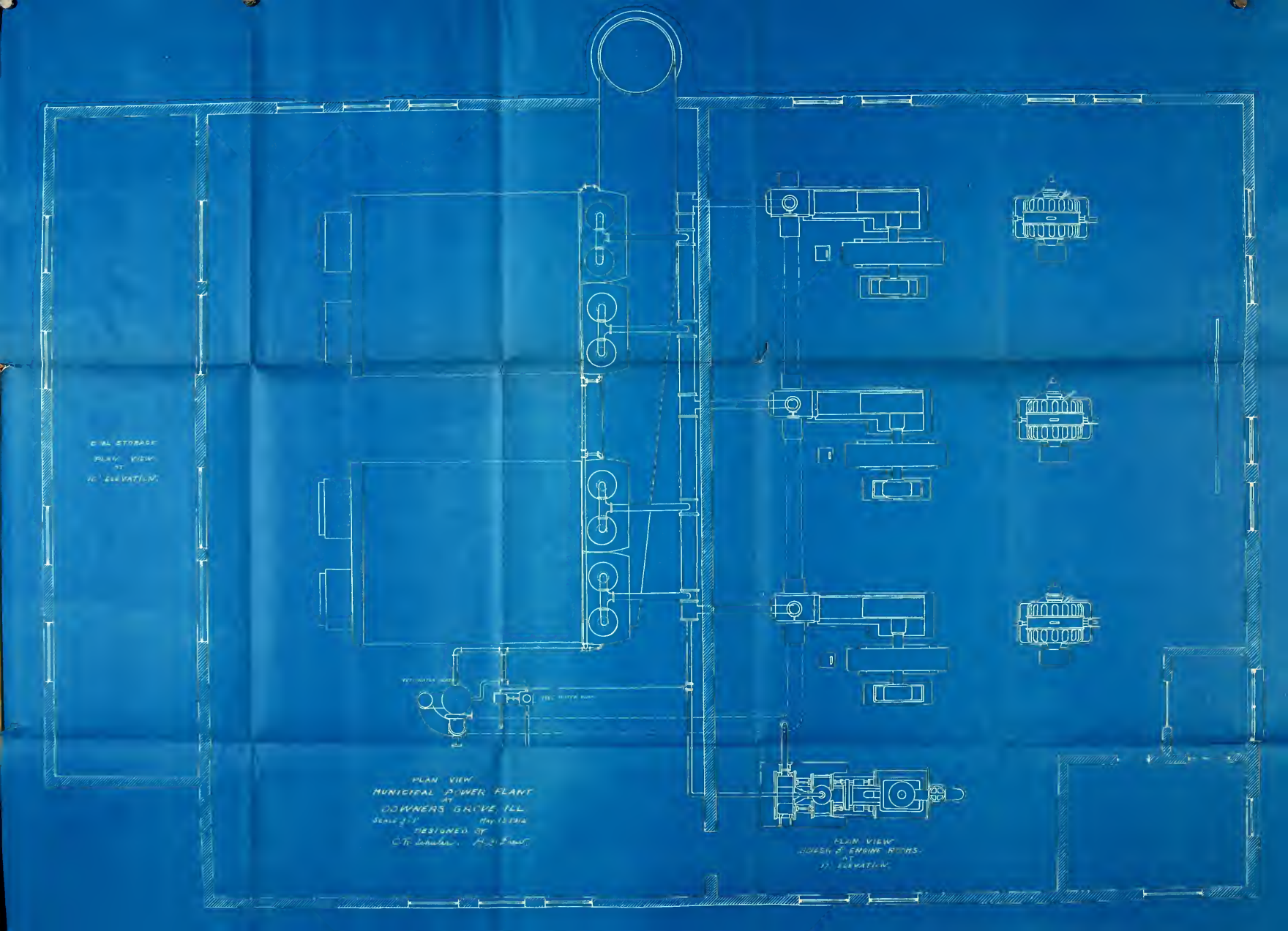
The net annual revenue, accruing to the village from the electric light system, is found by subtracting the expenses from the income as shown.

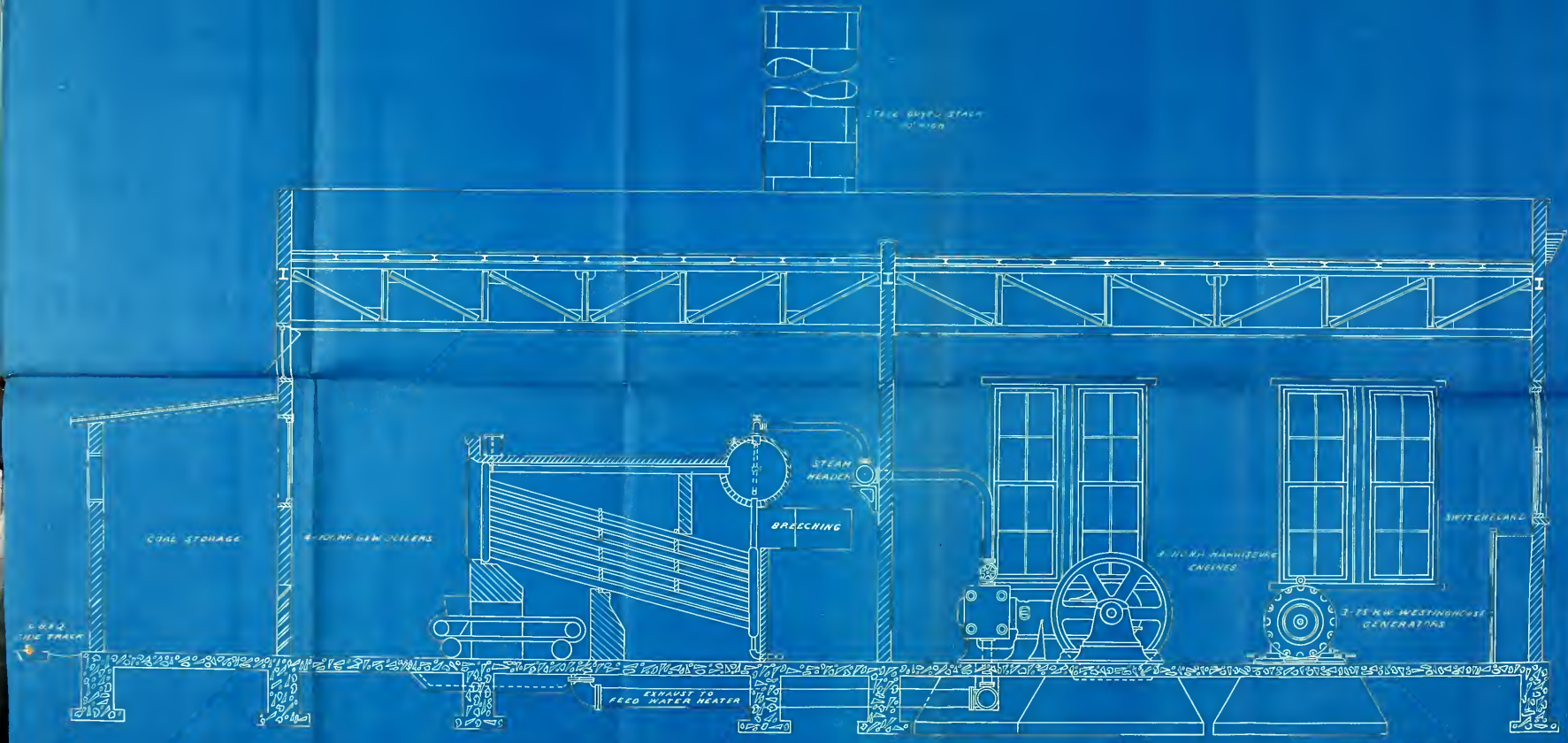
Annual income	$36800.00
Fixed charges and operating expenses	17100.00
Net annual revenue	19700.00

This annual revenue of $19700.00 is the net saving to the village by virtue of the citizens decision to retain the electric light plant. The proposed plant is designed to give absolutely reliable service and in this respect is equal to North Shore service. It must also be borne in mind that the

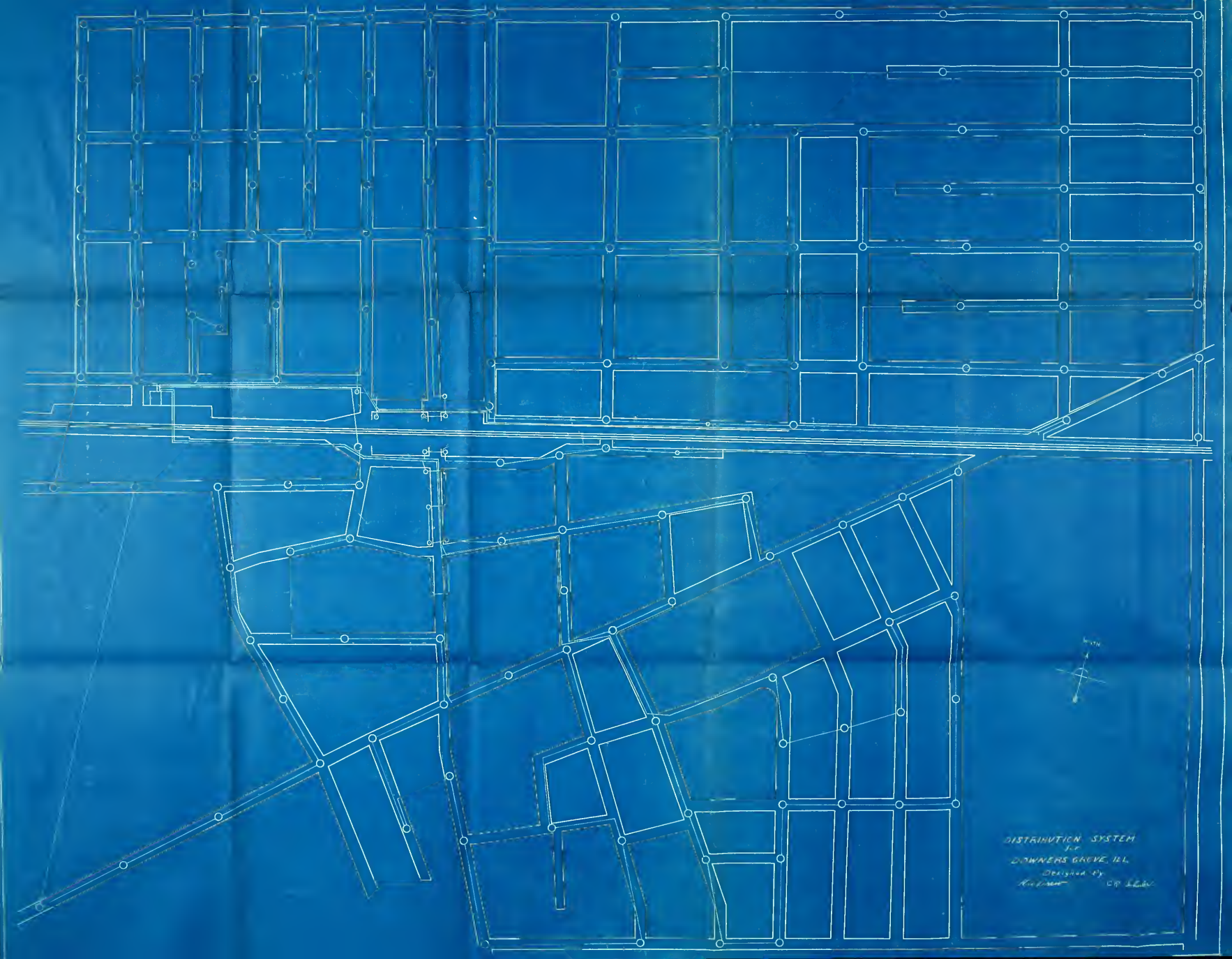
pumping station operates more efficiently when combined with the electrical plant, than when operated independently. Liberal allowances have been made thruout the calculations for all losses, expenses and costs, so that the savings figure is a conservative value. This figure is so large that in view of the character of the service in both cases, it proves conclusively the desirability of rehabilitation, in preference to the admission of a public service corporation.


Calculated Load Curve
Downers Grove
Power Plant
Total
Industrial
House Lighting
Street Lighting
Load (K.W.)
Time
0
20
50
80
120
160
200
12
2
4
6
8
10
12
2
4
P.M.
6
8
10
12
Noon


COAL STORAGE
PLAN VIEW
AT
10' ELEVATION.
PLAN VIEW
MUNICIPAL POWER PLANT
AT
DOWNERS GROVE, ILL.
SCALE 1/8"
DESIGNED BY
PLAN VIEW
BOILER & ENGINE ROOMS
AT
11' ELEVATION.



CROSS-SECTION
MUNICIPAL POWER PLANT
OF
DOWNERS GROVE, ILL.
Scale 1/4" — May 15, 1912
DESIGNED BY


DISTRIBUTION SYSTEM
for
DOWNERS GROVE, ILL.
Designed by
Reviewed by
C.P. LEAV.